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PATHOGENS ASSOCIATED WITH DRYLAND ROOT ROT IN EASTERN OREGON AND WASHINGTON

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INTRODUCTION

Root, crown, and foot (culm) rots in dryland areas are difficult to diagnose and often go unnoticed until whiteheads (prematurely ripening heads that yield shriveled or no grain) appear shortly before the crop matures. Several names are used interchangeably to designate the disease or pathogen. Disease names include Fusarium foot rot, dryland foot rot, Fusarium crown and root rot, crown rot, and common root rot. The name officially recognized by the American Phytopathological Society is common root rot. For reasons of clarity in the Pacific Northwest, the disease is named dryland root rot in this paper.

Confusion over the names of the disease is understandable in view of the complexity of dryland root rot. Several pathogenic fungi are capable of causing nearly identical symptoms and damage to winter and spring wheat and barley, many rotational crops, and grasses. The pathogens include but are not limited to *Fusarium culmorum*, *F. graminearum*, *F. avenaceum*, *Bipolaris sorokiniana* (also known as *Cochliobolus sativus*; and previously known as *Helmintho-sporium sativum*), and *Microdochium nivale* (previously known as *F. nivale*). These organisms typically occur as mixed pop-ulations in cereal production regions throughout the world, with proportions of each varying in response to climatic, cropping, and edaphic characteristics.

The dryland root rot fungi are considered "unspecialized" pathogens because they are capable of attacking any plant tissue they contact, providing conditions in the micro-environment at the tissue surface are favorable for infection. Infection typically occurs under the soil surface for non-irrigated cereals in semiarid climates, but may also occur in the foliar canopy in irrigated crops or in areas of higher rainfall. Several of these fungi cause head scab if conditions favor their spread to the head during cool, wet weather. *F. graminearum* is particularly well adapted for spreading to the head. Two forms (Group 1 and Group 2) of this pathogen are recognized. Group 1 is considered truly soilborne and has no known perfect stage. Group 2 forms fruiting structures (perithecia) capable of ejecting spores into the air. The perfect stage of *F. graminearum* Group 2 is named *Gibberella zeae*, the pathogen mostly associated with head scab of wheat and crown rot of corn.

The dryland root rot pathogens cause similar symptoms on underground plant parts, and similar damage to components of yield, yet they possess certain differences that influence their survival and pathogenicity. These differences cause the population of each specific pathogen, or its prevalence in a mixture, to vary among regions. The pathogens also have subtle differences for plant structures (crown roots, subcrown internode, crown, foliage, etc.) they infect preferentially. The biology of several dryland root rot pathogens has been studied in depth in Washington. Considerable attention has also been given to development of control practices for this disease. Much of the work was performed where *F. culmorum* was by far the dominant pathogen. Little of the disease control research in the Pacific Northwest has been done where *F. graminearum* is the principal pathogen, and none has been performed where *Fusarium* species were known to be intermixed with *B. sorokiniana*. During the course of plant pathological investigations throughout northcentral and northeast Oregon we have noted instances where either *F. graminearum* or *B. sorokiniana* appeared to be the primary pathogens causing necrosis of plant crown tissue. No concerted investigation of the geographic distribution of these pathogens or of disease etiology had been conducted in Oregon. It is possible that difficulties in controlling dryland root rot in Oregon could be related to differences in pathogen species and their response to control practices, as compared to earlier investigations in Washington.

F. culmorum and *B. sorokiniana* survive as spores either in plant residue or soil. *F. graminearum* and *F. avenaceum* survive mostly or entirely as mycelial fragments in plant residue. The pathogens can be seed-borne, providing immediate access to seedlings emerging from untreated seed. *F. culmorum* colonizes roots at points of injury, especially where crown roots penetrate crown tissue as they emerge. The principal sites for infection by *F. graminearum* and *F. avenaceum* depend on the vertical distribution of crop residue in the plow layer. Infections by *F. graminearum* occur mostly in crowns when residue is at the surface and through the subcrown internode, or at the seed when residue is incorporated or burned. *F. avenaceum* infects the coleoptile, sub-crown internode, crown roots and seminal roots during periods of abundant moisture. *B. sorokiniana* can infect all tissues below or above the soil surface. These pathogens all cause chronic infections of the plant. Measurable effects on yield seldom become apparent unless the plant is subjected to water stress and/or warm temperatures late in the growing season. However damage can also be substantial during very wet periods and in irrigated wheat.

Information on chemical control and genetic resistance for reducing damage from dryland root rot are not currently available in disease control guidelines for the Pacific Northwest. New fungicides are showing intermediate levels of promise for reducing disease severity and increasing yield (Smiley and others, unpublished results of seed treatment studies). Unfortunately, each species of pathogen involved in the dryland root rot complex appears to have a different sensitivity to each fungicide. Local and international research shows new promise for techniques to select varieties with improved levels of adult-plant tolerance to dryland root rot, however, the varieties are likely to respond differently to some pathogens.

Additional progress in minimizing damage from dryland root rot will require a more complete knowledge of the composition of the pathogen population in each geographic region. The objective of this study was to determine the identities of dryland root rot pathogens in northcentral and northeast Oregon. Initial findings made it imperative that the survey be expanded into other parts of Oregon and into Washington, so that results could be linked to and expanded upon the knowledge developed during studies in Washington two and three decades earlier.

METHODS

Winter wheat plants and soil were initially collected from 72 fields in eight Oregon counties during the spring of 1993. Counties included Wasco, Sherman, Gilliam, Morrow, Umatilla, Union, Wallowa, and Baker. Numbers of fields sampled were approximately proportional to acres of winter wheat harvested in each county during 1992, with an arbitrarily assigned minimum of two samples/county. Samples consisted of 15 or more plants collected while moving in a circle (30-50 foot diameter) located 100 to 200 feet inside each field. Symptoms of dryland root rot were never apparent in the foliage at the time plants were dug from the soil. Plants were collected at random with respect to field selection, field history, sampling loci within fields, and selection of individual plants. Approximately one pound of soil between drill rows was collected from the same subsampling sites where plants were collected. Plants were washed to remove soil and examine them for presence of all common diseases of roots and foliage (data not presented).

Crown tissue was dissected from 15 plants/field. Half of each crown segment was cultured in the laboratory on two media semi-selective for isolating either *Fusarium* or *Bipolaris*. Fungi that grew out of the tissue segments were transfered to a third culture medium for identification and, in the case of *F. graminearum*, an opportunity to identify the group type. Selected isolates were then placed into semi-permanent cultures for more exhaustive studies. Results of fungi isolated from crowns of winter wheat are reported in this paper.

Preliminary evaluation of results during 1993 revealed surprises that made it important to tie the present survey together with information collected in Washington during the 1960's and 1970's. The survey was immediately expanded during 1993 to encompass a total of 146 fields in two additional Oregon and seven Washington counties. Counties included Malheur and Jefferson in Oregon, and Benton, Walla Walla, Columbia, Adams, Lincoln, Whitman, and Asotin in Washington. After sampling was completed, Extension agents assisted in collecting information on field histories and the varieties planted.

The survey was continued in 1994 and expanded to include Klickitat and Franklin counties in Washington. Samples were collected from the in-crop field nearest that sampled during 1993, except for several sites that were eliminated to minimize samplings from adjacent fields; 142 fields were sampled, 83 in 10 Oregon counties and 59 in nine Washington counties.

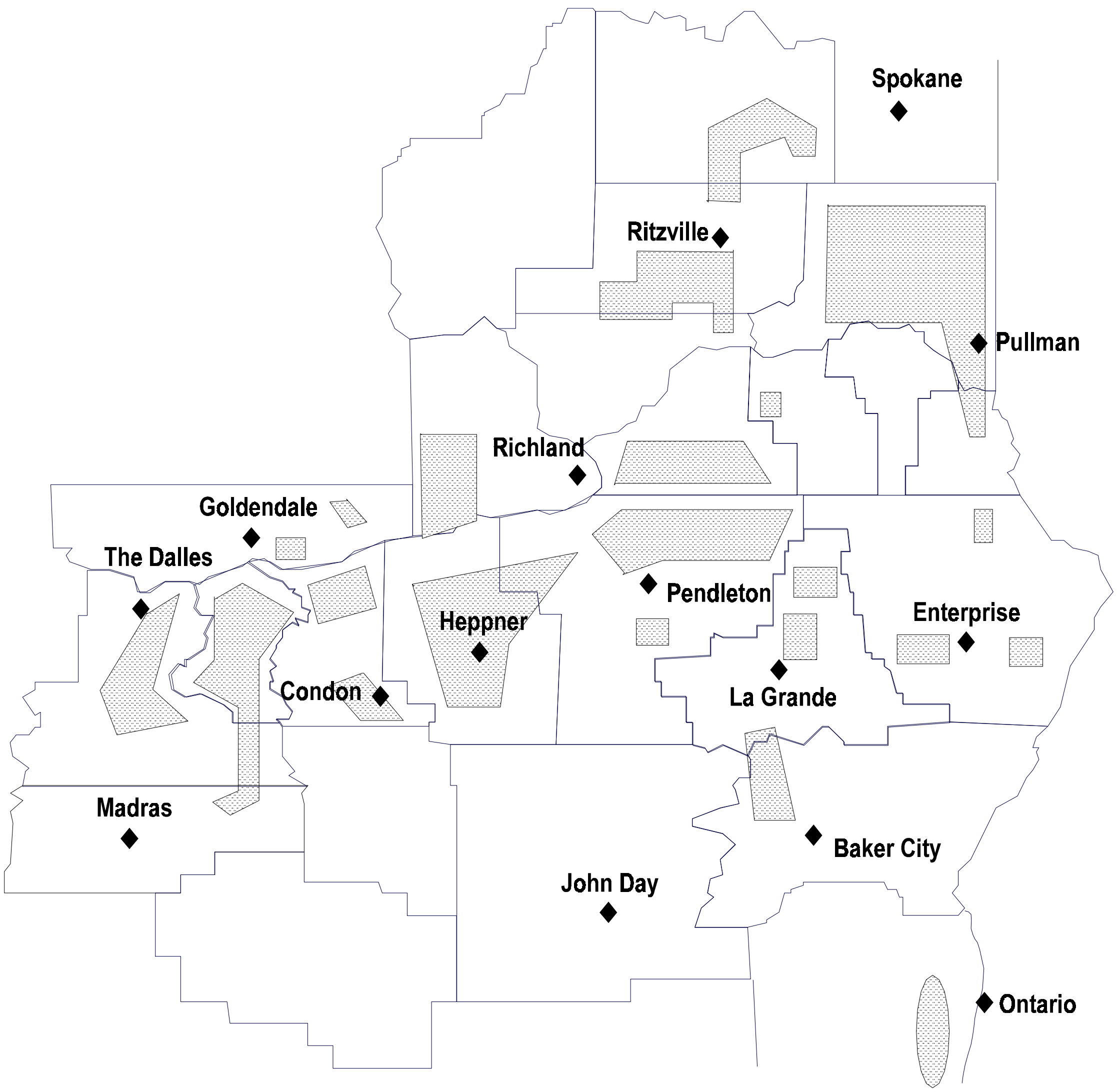
Soil samples are currently being evaluated for the presence of pathogens such as *F. culmorum*, which may survive as spores in soil. Results of this work may be used to expand information achieved with isolations made from plant tissue. Taxonomic and pathogenicity studies are also being conducted in the laboratory and greenhouse, using about 230 fungi isolated from plant tissue.

RESULTS AND DISCUSSION

Samples were collected from 178 fields in 10 Oregon counties and 110 fields in nine Washington counties. Regions included in the survey are illustrated in Figure 1. Numbers of wheat crowns excised from plants and plated onto culture media in the laboratory included 3,445 from Oregon and 1,945 from Washington. Approximately half of the 5,390 crowns from 288 fields were examined during each of the two years of this survey.

The 1991-1992 growing season had normal precipitation except for abnormally wet periods during April and July (refer to the last page of this publication). Excellent soil moisture in the summer fallow prompted many growers to plant winter wheat earlier than normal in the autumn of 1992, leading

Figure 1. Sampling regions for surveys of dryland root rot pathogens in 288 fields located in 10 Oregon and nine Washington counties during 1993 and 1994.



to numerous instances of severe dryland root rot. Infections in some fields became intense as early as November 1992. The winter and spring of the 1992-1993 season were very wet, leading to 20 percent higher than normal precipitation for the crop year. The summer, autumn, and winter of the 1993-1994 season were very dry. Plantings were often delayed until rains began during November. Plants showed signs of drought stress as early as April 1994.

Summaries of percentages of fields yielding isolates of the dryland root rot fungi in each state are presented in Table 1. *F. graminearum* was isolated more frequently than *F. culmorum* during each year in each state. The third-most prevalent pathogen was *F. avenaceum* during 1993 (wet year), and *M. nivale* during 1994 (dry year). The least prevalent pathogen was *B. sorokiniana* during 1993 (wet year), and *F. avenaceum* during 1994 (dry year). Further evidence for seasonal fluctuation among pathogens

Table 1. Numbers of fields sampled and percentages of fields yielding isolates of dryland root rot pathogens during surveys conducted in eastern Oregon and Washington during 1993 and 1994.

Pathogen species	1993			1994		
	OR	WA	OR+WA	OR	WA	OR+WA
	- percentages of fields with isolates -					
Fusarium graminearum	43	59	49	31	23	28
Fusarium culmorum	24	38	29	16	13	15
Fusarium avenaceum	13	5	18	1	3	2
Bipolaris sorokiniana	2	6	3	5	22	12
Microdochium nivale	6	10	8	19	27	23
Number of fields sampled	95	51	146	83	59	142

associated with wheat crowns is apparent in Tables 2 and 3. These data, literature from other regions and countries, and previous work in Washington, indicate that seasonal variability in pathogen prevalence was due to the different weather patterns during the two years of this survey.

One or more of the five pathogens associated with dryland root rot were present in each Oregon county during one or both years (Table 2). The most dominant pathogens region-wide in Oregon were *F. graminearum* and *F. culmorum*, but *M. nivale* was prominent in two counties where elevations typically exceed 3,000 feet and average soil temperatures tend to be cooler than in other areas. *B. sorokiniana* was present in six of the 10 counties, but did not appear to be a dominant member of the root rot complex.

The pathogen complex was also diverse in Washington (Table 3). Either *F. graminearum* or *F. culmorum*, or both, were present in each area. The lack of isolation of these pathogens in Columbia County was considered an artifact; it is clear that dryland root rot also occurs in that county. Lack of isolation of any of these pathogens does not infer that they are not present in the field. It was of interest that *B. sorokiniana* and *M. nivale* each appeared dominant in three Washington counties during 1994.

Dryland root rot pathogens evolved with relatively little specificity for the types of tissue or the species of plants they are able to infect, or to survive upon. The frequent identification of each pathogen throughout eastern Oregon and Washington, and the seasonal variability perceived to occur for their dominance in association with wheat crowns, indicates that all may be important in some areas during some years. The complexity of this situation indicates that chemical, cultural, and genetic disease management strategies must be developed to improve overall plant health rather than specifically targeting to one or two pathogen species. This is a challenging task but previous and current information illustrates that it is achievable. For instance, a growing body of evidence suggests that certain combinations of fungicides, selection of varieties, timing, placement and rate of nitrogen application, type of rotation, and management of surface residue provides more season-to-season stability for minimizing damage from dryland root rot than is true for other choices among these crop and soil management variables.

Table 2. Identities and relative prevalence† of dryland root rot pathogens‡ isolated from Oregon winter wheat fields sampled during surveys conducted during 1993 and 1994.

County	1993						1994					
	Fields/ county	Fg	Fc	Fa	Bs	Mn	Fields/ county	Fg	Fc	Fa	Bs	Mn
Baker	2					X	1					
Gilliam	13	X	X	x	x		9	X	x			x
Jefferson	2					X	2					
Malheur	5	X	X			x	5					
Morrow	9	x	x	x			7	X	X		x	X
Sherman	19	X	X	x			16	X	x	x	x	x
Union	4			x	x	x	4					x
Umatilla	29	X	x	X	x	x	23	x	x		x	X
Wallowa	2		X				6					
Wasco	10	x					10	X			x	

† An 'X' indicates the pathogen was dominant among isolates and an 'x' indicates the pathogen was isolated from at least one field in the county.

‡ Fg = *Fusarium graminearum*; Fc = *F. culmorum*; Fa = *F. avenaceum*; Bs = *Bipolaris sorokiniana*; Mn = *Microdochium nivale*.

Table 3. Identities and relative prevalence† of dryland root rot pathogens‡ isolated from Washington winter wheat fields sampled during surveys conducted during 1993 and 1994.

County	1993						1994					
	Fields/ county	Fg	Fc	Fa	Bs	Mn	Fields/ county	Fg	Fc	Fa	Bs	Mn
Adams	5	x	X		x		8	X	x		X	X
Asotin	3	X					4	x				
Benton	11	X		x		x	9	x			x	x
Columbia	2						2					
Franklin	0						1	X				
Klickitat	0						5		x			x
Lincoln	7	x	X		x	x	7		X		X	x
Walla Walla	13	X	x	x	x		10	X	x	x	x	X
Whitman	10	X	x	x		x	13				X	X

† An 'X' indicates the pathogen was dominant among isolates and an 'x' indicates the pathogen was isolated from at least one field in the county.

‡ Fg = *Fusarium graminearum*; Fc = *F. culmorum*; Fa = *F. avenaceum*; Bs = *Bipolaris sorokiniana*; Mn = *Microdochium nivale*.

Authors of this paper are conducting studies to improve these strategies for reducing damage from dryland root rot in the Pacific Northwest.

Non-pathogenic as well as pathogenic fungi were isolated during this study. Fungi isolated from 2,550 wheat crowns during 1993 included 831 *Fusarium* isolates representing 19 species. Species isolated from more than 50 crowns included *F. oxysporum* (260 isolates), ***F. graminearum*** (254; all except one of which was Group 1), ***F. culmorum*** (74), and *F. reticulatum* (67). Other fungi capable of causing dryland root rot were isolated less frequently, including 32 of ***F. avenaceum***, 16 of ***M. nivale***, 8 of ***B. sorokiniana***. Also enumerated but not reported here were isolates of the following species of *Fusarium*: *acuminatum, compactum, decemcellulare, dimerum, episphaeria, equiseti, lateritium, moniliforme, sambucinum, semitectum, solani, sporotrichioides, tricinctum,* and *trichothecoides*. Fungi that were not enumerated included species of *Alternaria*, *Aspergillus*, *Cephalosporium*, *Chaetomium*, *Cladosporium*, *Mucor*, *Penicillium*, *Pythium*, *Rhizoctonia*, *Stemphyllium*, and *Verticillium*.

Fungi isolated from 2,840 wheat crowns during 1994 included 487 *Fusarium* isolates representing 19 species. Species isolated from 50 crowns or more included ***F. graminearum*** (108 isolates; all were Group 1), *F. reticulatum* (101), *F. oxysporum* (93), and *F. solani* (50). Other fungi capable of causing dryland root rot were isolated less frequently, including 37 of ***M. nivale,*** 30 of ***B. sorokiniana,*** 22 of ***F. culmorum***, and 3 of ***F. avenaceum***. Also enumerated but not reported here were isolates of the following species of *Fusarium*: *acuminatum, dimerum, equiseti, graminum, lateritium, merismoides, moniliforme, proliferatum, sambucinum, scirpi, sporotrichioides, sulphureum,* and *tricinctum*. Fungi that were not enumerated included species of *Alternaria*, *Cephalosporium*, *Cladosporium*, *Fumago*, *Heterosporium*, *Pythium*, *Rhizoctonia*, *Stemphyllium*, and *Verticillium*.

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